INTERIM STATUS REPORT

NASA RTOP UPN 397-04-05

REVIEW AND DOCUMENT RELIABILITY ISSUES WITH HYBRID MICROCIRCUITS

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Summarv

Hybrids, including multi-chip-modules (MCMs), are becoming increasingly used for NASA/JPL space applications, and the magnitude of reliability problems and concerns could increase proportionate!y. This RTOP intends to review and document past problems and failures with hybrids used by NASA, industry, and other government agencies, in order to compile a comprehensive document on problems experienced with this technology.

Overall objectives will be to identify failure modes, mechanisms, reliability issues, and performance problems. "Lessons learned" will be documented in the final report, and recommendations will be given which are intended to avoid similar problems and failures in the future. Some emerging trends indicate that there is a need to improve QA techniques and surveillance, in order to avoid problems and failures caused by EOS/ESD, contamination, bad die, and epoxies.

REVIEW AND DOCUMENT RELIABILITY ISSUES WITH HYBRID MICROCIRCUITS

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Presented to the NASA Parts Steering Committee

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ELECTRONIC PARTS RELIABILITY

BACKGROUND

- Hybrids are increasingly used for NASA and military applications.
  - Hybrids with acceptable digital signal delays still offer the best answer for combinations of analog and power parts, active and passive, CMOS and bipolar, for which PC boards or monolithic technology doesn't yet exist.
  - Hybrids can achieve much of the size advantage of ASICs without the cost of ASIC development (Semiconductor International, Oct. '93, p. 57).
  - Mixing different technology parts coupled with low cost changes, quick turn prototypes, and shorter production runs, the hybrids offer functions not yet available with other technologies.
- Reliability concerns have also increased proportionately. Loss of a hybrid for avoidable failures can represent an enormous financial and functional penalty.
  - Recent examples of hybrid failures include:

    HUBBLE SPACE TELESCOPE - G4 and G6 gyro controller
    NSCAT - Crystal Oscillator
    DOD - Transmitter/Receiver
    CASSINI - Solid State Power Switch (under development)

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ELECTRONIC PARTS RELIABILITY

OBJECTIVES

- Improve the reliability of hybrids used in NASA programs by identifying past and current problems and recommending corrective actions.

DELIVERABLES AND BENEFITS

- A report will be prepared by JPL to identify problems and failures experienced with hybrids, and to provide recommendations and corrective actions.

- This report will be submitted to NASA and NASA Contractors for their information and guidance to avoid user-induced hybrid failures.

- This report will also be forwarded to DESC for them to work with hybrid manufacturers to implement applicable recommendations and corrective actions, intended to reduce future hybrid problems and failures.

APPROACH

- Obtain baseline data on hybrid problems and failures from JPL history, literature searches, and site visits at NASA centers, selected industries, and other government agencies.

- Prepare an initial draft of the data, findings, and preliminary conclusions and recommendations, for critical review and additional inputs by the participants.

- Publish a report.

- Update the report with annual supplements.

JPL HYBRID OPERATIONAL FAILURES

	Number	Percentage
Electrical Overstress/Electrostatic Discharge (EOS/ESD)	5	26%
Foreign Material/Contamination	4	21%
Poor Electrical Contact at Epoxy Joint	4	21%
Gate Oxide Failures	2	11%
Broken or Missing Bondwire	2	11%
Cracked Substrate	1	5?40
Poor Solder Joint	1	5 %
	19	100%

NASA HYBRID OPERATIONAL FAILURES

	Number	Percentage
Bondwire Failure	10	33.3 %
Electrical Overstress/Electrostatic Discharge (EOS/ESD)	8	26.7 %
Cracked Element	4	13.3 %
Foreign Material/Contamination	3	10.0 %
Device Dielectric Failure (Mfg. Defect)	2	6.7 %
Poor Electrical Contact at Epoxy Joint	1	3.3 %
Poor Solder Joint	1	3.3 %
Package Hermeticity Failure	1	3.3 %
	30	100%

JPL HYBRID DPA/PCA PROBLEMS

	Number	Percentage
Hermeticity Test Failure	7	22%
Failed SEM Metal Examination	5	16%
Wire Interconnect Problems	5	16%
Excessive Moisture (PGA Test)	5	16%
Epoxy Die Attach Problems	3	10%
Foreign Material/Contamination	3	10%
Scratches on Die	3	10%
	31*	100%

*There were 15 DPA or PCA lots inspected, with from 1 to three parts per lot, having a total of 31 causes for lot rejections.

ELECTRONIC PARTS RELIABILITY

NASA HYBRID DPA/PCA PROBLEMS

	Number	Percentage
Foreign Material/Contamination	95	31.5 %
Wire Interconnect Problems	70	23.2 %
Scratches on Die	31	10.3 %
Failed SEM Metal Examination	23	7.6 %
Epoxy Die Attach Problems	23	7.6 %
Oxide Flaw Under Metal on Die	19	6.3 %
Package Pin Plating	10	3.3 %
Excessive Moisture (RGA Test)	7	2.3 %
Fractured Element	7	2.3 %
Diffusion Defect on Die	6	2.070
Hermeticity Test or Other Pkg Sealing Failure	5	1.6 %
Poor Laser Trim on Resistor (Detritus)	3	1.0 %
EOS From Lid Sealing	2	0.7 %
Poor Capacitor Terminations	1	0.3 %
	302	100 %

OPERATIONAL FAILURES FROM HYBRID LITERATURE

	Number	Percentage	Reference
Foreign Material/Contamination	6	54.5%	1,3-5, 11, 13
Failed Wirebond	3	27.3%	6, 9,10
Cracked Substrate	1	9.1%	7
Defective Chip Design or Fabrication	1	9.1%	8
	11	100?40	

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PARTICLE GETTER EXPERIENCE BY A MAJOR HYBRID MANUFACTURER

- **HAS USED A SILICONE-BASED PARTICLE GETTER IN MILITARY, MEDICAL, AND COMMERCIAL HYBRIDS FOR 15 TO 20 YEARS -- ZERO PROBLEMS KNOWN OR REPORTED**

- **CUSTOMER MIX SPREADS ACROSS ALL FOUR COMBINATIONS; USE OF GETTER (YES/NO) AND PIND TESTING (YEWNO)**

PIND MANUFACTURING RESULTS

GENERAL PRODUCT CLASS	CUSTOMER REQUIREMENT GETTER	CUSTOMER REQUIREMENT PIND	PRODUCT YIELD PASSING PIND
HI-REL	YES	YES	>99%
HI REL	YES	NO'*	>99%
HI-REL	NO*	YES	>96%
COMMERCIAL	NO	NO**	≈ 65 - 70%

* SPECIAL **HI-REL CLEANING PROCEDURES AND PRECAUTIONS ARE EMPLOYED** (COST COMPONENT)

** **EXPERIMENTAL EXPERIENCE ON NON-MARKETED PRODUCTS (INTERNAL TESTING)**

[illegible]hybrid.doc/word

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SOME SPECIAL HI-REL CLEANING PROCEDURES AND PRECAUTIONS USED BY A MAJOR HYBRID MANUFACTURER

- SPRAY CLEANING
- SHOCK AND SHAKE UPSIDE-DOWN PACKAGE WITH TEMPORARY GETTER-COATED LID
- CARRY OUT EUTECTIC DIE ATTACH IN DRY BOX
- STORE UNSEALED PACKAGES IN CLASS 1000 CABINETS, OR BETTER
- POSITION LIDS IN PLACE BEFORE GOING TO SEALER

ELECTRONIC PARTS RELIABILITY

COMMENTS ON GETTERS BY VENDOR 1

- COMMERICALLY AVAILABLE UNFILLED SILICONE GEL
- THINNED WITH XYLENE
- LONG TERM RETENTION TO >150°C
- DON'T SEE DETERIORATION UP TO 200°C

- USED ON MOST OF THEIR PRODUCTS FROM LATE 70'S TO THE PRESENT
  - → COMMERCIAL, MILITARY CLASS H AND B, MEDICAL, TELECOMMUNICATIONS, RELAYS. TEST INSTRUMENTS, DATA PROCESSING

- NO FIELD PROBLEMS REPORTED WITH GETTERS
  - → NO RGA FAILURES
  - → NO LOOSENED PARTICLES

- GETTERS NOT USED IN AUTOMOBILE HYBRIDS

Failure Mechanisms Observed by Vendor 1

Problems With Internal Fabrication

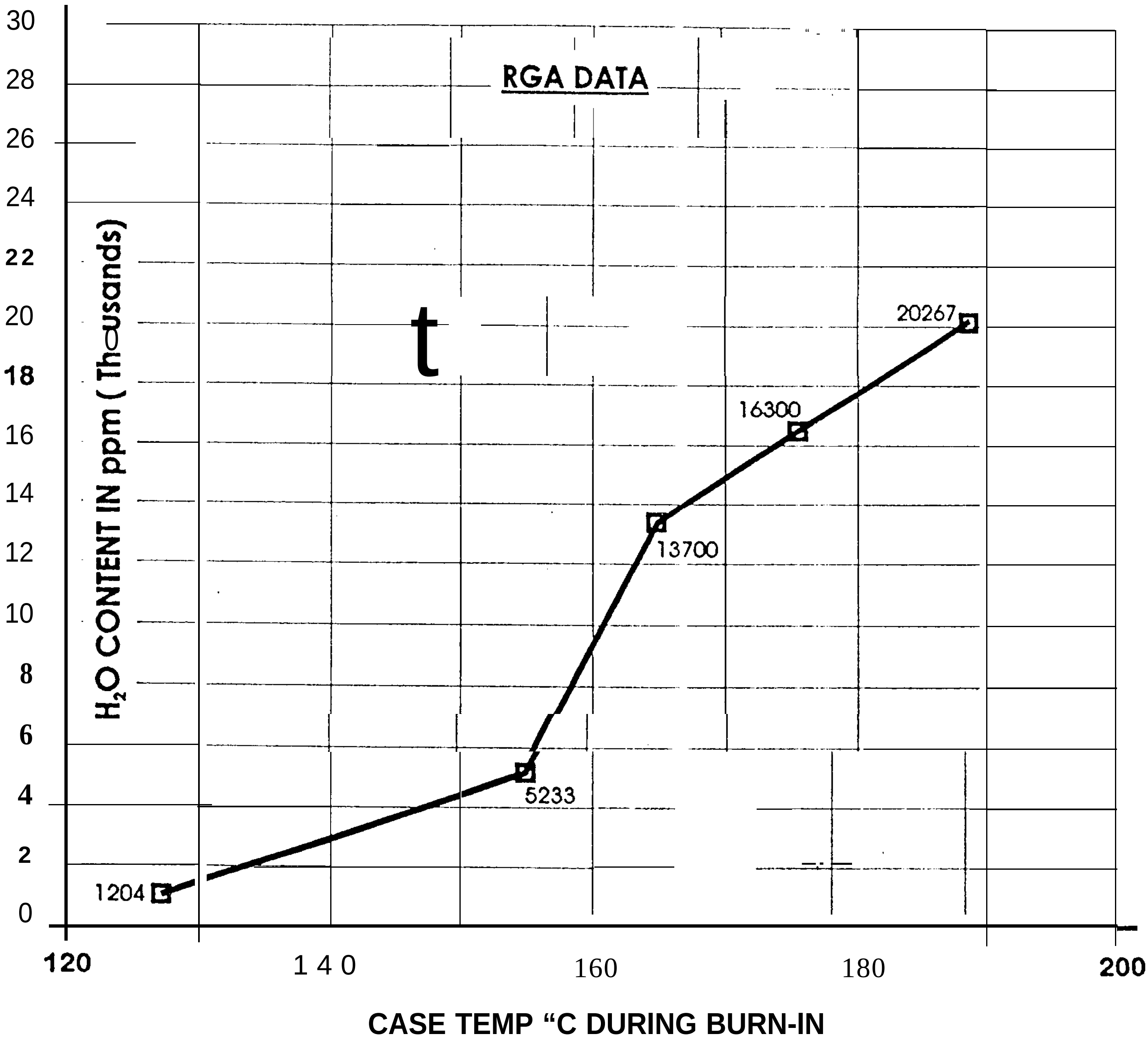
- Die shear failure at qualification due to poor epoxy bonding to gold pads on high temperature co-fired ceramics.
- Contamination and foreign material observed at **pre-seal** inspection.
- Corrosion from residual cleaning solvents not removed prior to subsequent plasma cleaning.
- Poor die attachment and high electrical contact resistance due to residual adhesive from carrier membrane transferred to the back of die.
- Epoxy **"bleed** out" from under dice, May be cleaned with 0_2 plasma.
- Wire bond failure due to contamination from **"dirty" DI** water used in cleaning operations.

Failure Mechanisms Observed by Vendor 1

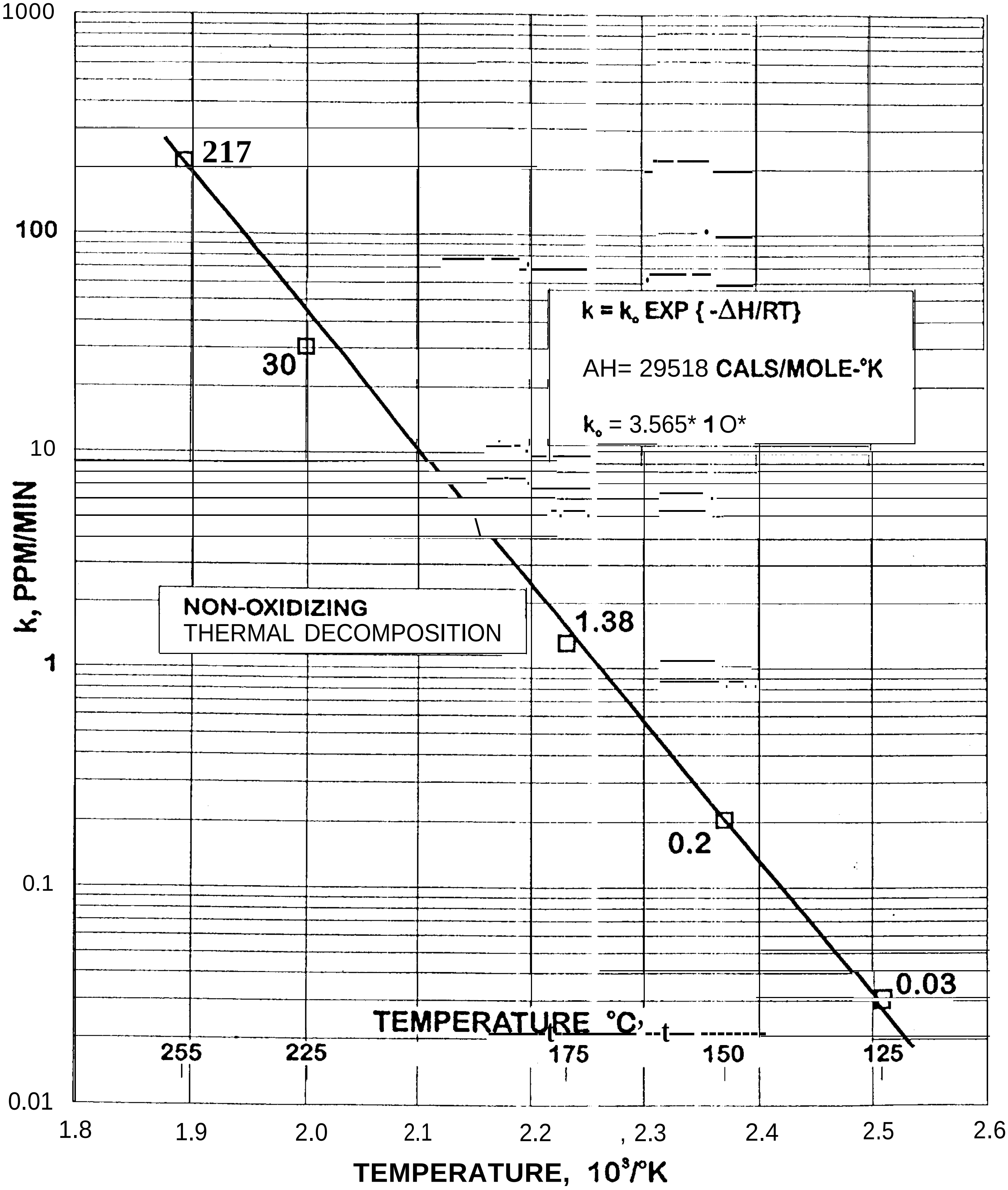
Problems Related To **Die** Manufacture

- Failure of **wirebond or** bond pad due to excessive Si **alloying** into the Al bond pad.
- Failure of wirebond or bond pad due to excessive **Cu** doping of the Al.
- Electrical failure of die.

HYBRID BURN-IN RESULTS
WATER CONTENTS VS. CASE TEMPERATURE



JPL EXPERIMENTAL DATA
THERMAL DECOMPOSITION OF A CURED, COMMERCIAL SILVER-FILLED EPOXY PASTE



JPL EXPERIMENTAL DATA

DC RESISTANCE VALUES IN OHMS OF A CURED SILVER-FILLED EPOXY PRE-FORM

	←CURE→	←——— THERMAL EXPOSURE		——→
	1/2 HR @ 150°C	+ 16 HRS @ 125°C	+ 10 SEC @ 245°C	+ 8 MIN @ 240°C
ALLIGATOR TEETH	< ≈ 0.001	0.07	0.07	0.07
ALLIGATOR NOSE	0.001	0.07	0.07	0.07
Ag ELECTRODES	0.0185	0.0135	0.0125	0.00325
	ρ = 0.458 Ω-CM	0.345 Ω-CM	0.318 Ω-CM	0.0826 Ω-CM

- SURFACE ON HEATING BECAME HARDER, TOUGHER, AND YELLOWED (ORIGINALLY SILVER IN COLOR)

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ELECTRONIC PARTS RELIABILITY

SUMMARY

- Hybrid failures are a NASA/DOD problem
- Hybrid failures are reported as far back as the 1960s, and continue today
- Some hybrid failure mechanisms may migrate into multi-chip-modules (MCM)
- Most frequent operational hybrid failure at JPL found to be EOS/ESD

EXAMPLES EMERGING FROM THIS STUDY

- Need to implement improved handling procedures for EOS/ESD safety, and for die screening and pre-cap visual inspection
- Need for better understanding of the correct use of epoxies